

AD-A051 457    WENTWORTH INST BOSTON MASS                          F/G 4/1  
DESIGN AND FABRICATION OF TRANSPORT SPHERES FOR HIGH VACUUM USE--ETC(U)  
AUG 76 M MCDONALD    F19628-74-C-0014  
UNCLASSIFIED    NL  
SCIENTIFIC-3    AFGL-TR-77-0307



END  
DATE  
FILED  
4 -78  
DDC

ADA 051457

AFGL-TR-77-0307

Q  
A

DESIGN AND FABRICATION OF TRANSPORT SPHERES FOR  
HIGH VACUUM USE

Martin McDonald

Wentworth Institute of Technology  
550 Huntington Avenue  
Boston, Massachusetts 02115

AD No.  
DDC FILE COPY



31 August 1976

Scientific Report #3

Approved for public release; distribution unlimited.

This research was sponsored by the Defense Nuclear Agency under Subtask K11BAXHX504, Work Unit 04, entitled "Ion Composition Measurements to Define the Physical Causes of Equatorial Ionospheric Irregularities."

AIR FORCE GEOPHYSICS LABORATORY  
AIR FORCE SYSTEMS COMMAND  
UNITED STATES AIR FORCE  
HANSOM AFB, MASSACHUSETTS 01731

**Qualified requestors may obtain additional copies from the Defense Documentation Center. All others should apply to the National Technical Information Service.**

(19) REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER 18 AFGL-TR-77-0307	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER 90
4. TITLE (and Subtitle) DESIGN AND FABRICATION OF TRANSPORT SPHERES FOR HIGH VACUUM USE.	5. TYPE OF REPORT & PERIOD COVERED Scientific - Interim report,	
6. AUTHOR(s) 10 Martin McDonald	7. PERFORMING ORG. REPORT NUMBER Scientific Research - 3	8. CONTRACT OR GRANT NUMBER(s) F19628-74-C-0014
9. PERFORMING ORGANIZATION NAME AND ADDRESS Wentworth Institute of Technology 550 Huntington Avenue Boston, Massachusetts 02115	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 61102F 66870301	11. REPORT DATE 31 August 1976
11. CONTROLLING OFFICE NAME AND ADDRESS Air Force Geophysics Laboratory Hanscom AFB, Massachusetts 01731 Monitor/Robert V. Pieri, Capt, USAF/LKD	12. NUMBER OF PAGES 25	13. SECURITY CLASS. (of this report) Unclassified
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) 12 13p, 16 6683 K11BAXH	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE	15. DECLASSIFICATION/DOWNGRADING SCHEDULE MR 20 APR 78
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release: distribution unlimited	17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report) This research was sponsored by the Defense Nuclear Agency under Subtask K11BAXHX504, Work Unit 04, entitled "Ion Composition Measurements to Define the Physical Causes of Equatorial Ionospheric Irregularities."	
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Electropolish Diversy Clean Electron Beam Weld T.I.G. Weld	Hydro-forming Hexamethydisilazane Silation Process Transport Sphere	
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The material in this manuscript describes the design and development of an efficient cost effective method of transporting air samples obtained in high altitude balloon launched flights.		

373 800

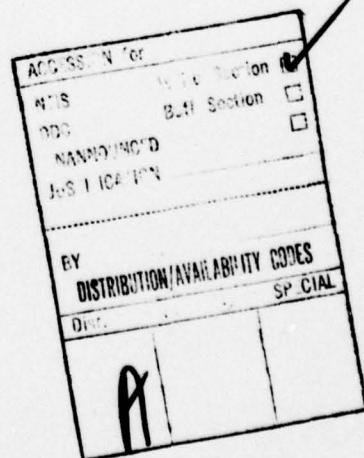
48

## TABLE OF CONTENTS

1.0	INTRODUCTION	1
2.0	REQUIREMENTS	1
3.0	DESCRIPTION	1
3.1	Gas Transport Sphere - Model I	1
3.2	Gas Transport Sphere - Model II	5
3.3	Gas Transport Sphere - Model III	5
3.4	Silation Process	8
4.0	CONCLUSION	9

## LIST OF ILLUSTRATIONS

<u>Figure</u>	<u>Description</u>	
1	Gas Transport Sphere (Mod I)	2
2	Gas Transport Sphere (Mod II)	4
3	Gas Transport Sphere (Mod III)	6
4	Silation Process, Sphere	7



LIST OF CONTRIBUTORS

The following individuals have contributed in various phases  
to this report:

Otto Molter, Sr. Exp. Machinist

Amy Gaiennie, Secretary

Design and Fabrication of Transport  
Spheres for High Vacuum Use

1.0 INTRODUCTION

During this period, Wentworth Institute of Technology supported the efforts of the Whole Air Sample Lab of the Composition Branch, AFGL, in the design and fabrication of components, assemblies and related equipment used in the study of atmospheric composition. This included conducting the necessary engineering liaison with AFGL for the purpose of establishing design parameters of instruments; designing, in mechanical detail, components and assemblies; fabricating items resulting from this design; determining the needs for possible re-design, and making recommendations for further modifications.

2.0 REQUIREMENTS

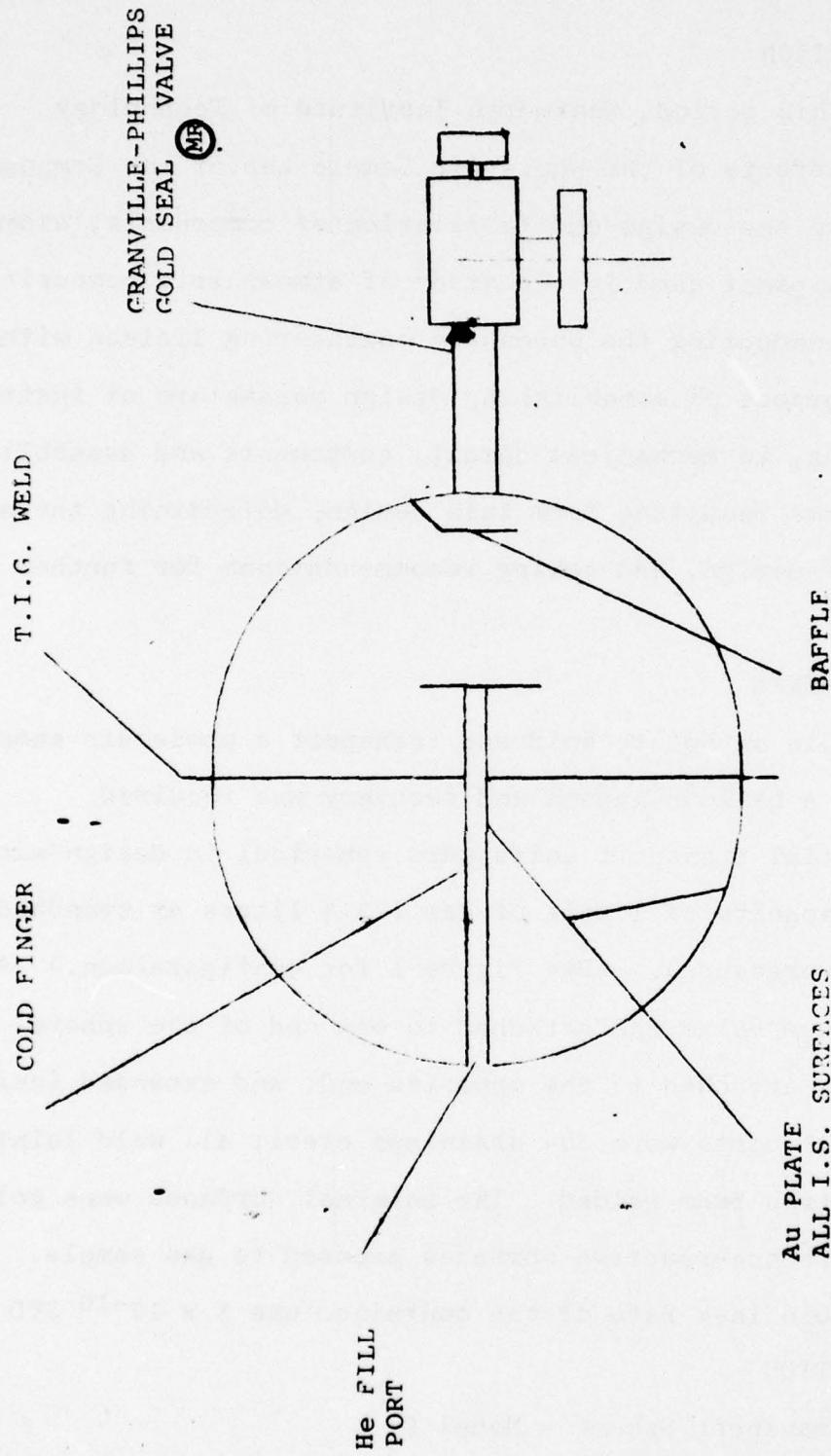
A reliable method to hold and transport a whole air sample gathered after a balloon launch and recovery was required.

The initial transport units were spherical in design with a volumetric capacity of 1 mole of gas (22.4 liters at standard atmosphere and pressure). (See Figure 1 for configuration.) An ultra-high vacuum valve was attached to one end of the sphere. A cold finger was attached to the opposite end; and extended inside the sphere. All parts were 304 stainless steel; all weld joints were T.I.G. or Electron Beam welded. The internal surfaces were gold-plated to insure non-reactive surfaces exposed to gas sample. The maximum allowable leak rate of the container was  $5 \times 10^{-10}$  STD cc/sec.

3.0 DESCRIPTION

3.1 Gas Transport Sphere - Model I

The hemispheres were generated by spin forming and required a pickling process to remove the surface scale. After the required



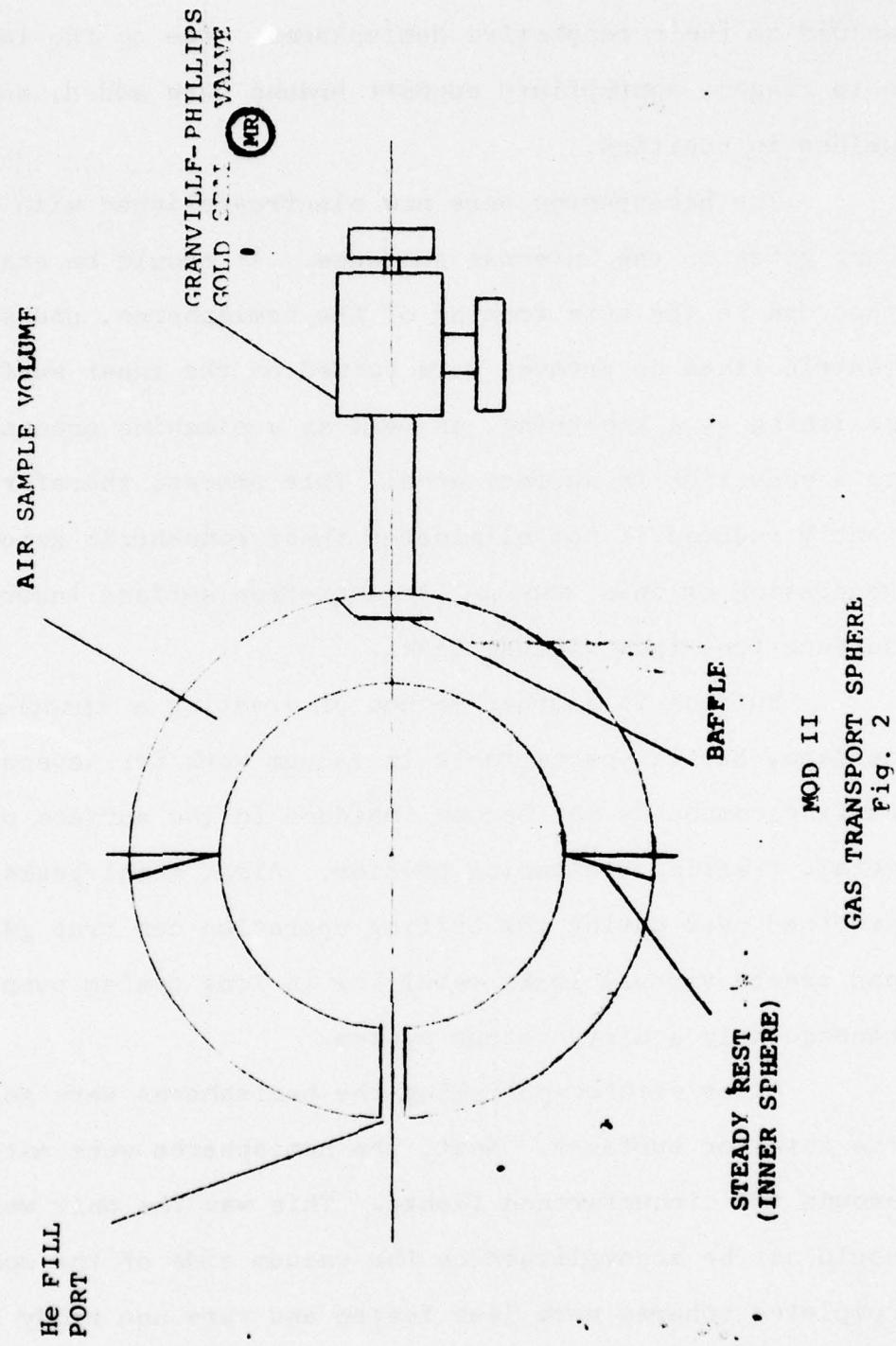
MOD I  
TRANSIT SPHERE  
Fig. 1

machining of the hemispheres, the cold finger and valve were T.I.G. welded to their respective hemispheres. Due to the length of the cold finger, appropriate support braces were added, and T.I.G. welded in position.

The hemispheres were now electro-polished with particular care given to the internal surfaces. It should be stated here that due to the spin forming of the hemispheres, undesirable concentric lines or grooves were formed on the inner surfaces. Electro-polishing -- a smoothing, as well as a cleaning process -- leads to a reduction in surface area. This process therefore, significantly reduced if not eliminated these concentric grooves. The generation of this smooth, scratch-free surface insures a clean surface free from virtual leaks.

Buffing is another method of creating a smooth, scratch-free surface, but is unacceptable in vacuum work for several reasons. Buffing compounds may become imbedded in the surface pores of the metal, creating a cleaning problem. Also, metal peaks bent and smoothed over during the buffing operation can trap gas particles, and create virtual leaks resulting in long system pump down and consequently a dirty vacuum system.

After electro-polishing, the hemispheres were gold-plated on the interior surfaces. Next, the hemispheres were mated and welded around the circumference flange. This was the only weld which could not be accomplished on the vacuum side of the spheres. The completed spheres were leak tested and were now ready for lab tests prior to flight. Figure 1 describes the general configuration of these transport spheres.



### 3.2 Gas Transport Sphere - Model II

Prior to the next balloon flight, new transport spheres were designed and fabricated incorporating one modification. The cold finger was no longer a tube extending into the sphere, but an internal sphere with an external volume of 11 liters. This, of course, reduced the gas handle volume to slightly more than a half mole, or 12.4 liters. These new parameters were still within acceptable limits for effective sample gathering.

The external configuration remained the same as Mod I, but the inner sphere was fabricated from hydro-formed hemispheres. This method of forming left the inner and outer surfaces of the hemispheres in excellent condition. The hemispheres were electro-polished with particular attention given to surfaces exposed to the vacuum side (gas contact).

To restrict movement, the inner sphere was supported at four points around its circumference between inner and outer spheres. The outer hemispheres were welded around the circumference, and leak tested.

These spheres were not gold-plated, which allowed the comparison between a gold-plated and unplated surface. The Mod II configuration is shown in Figure 2.

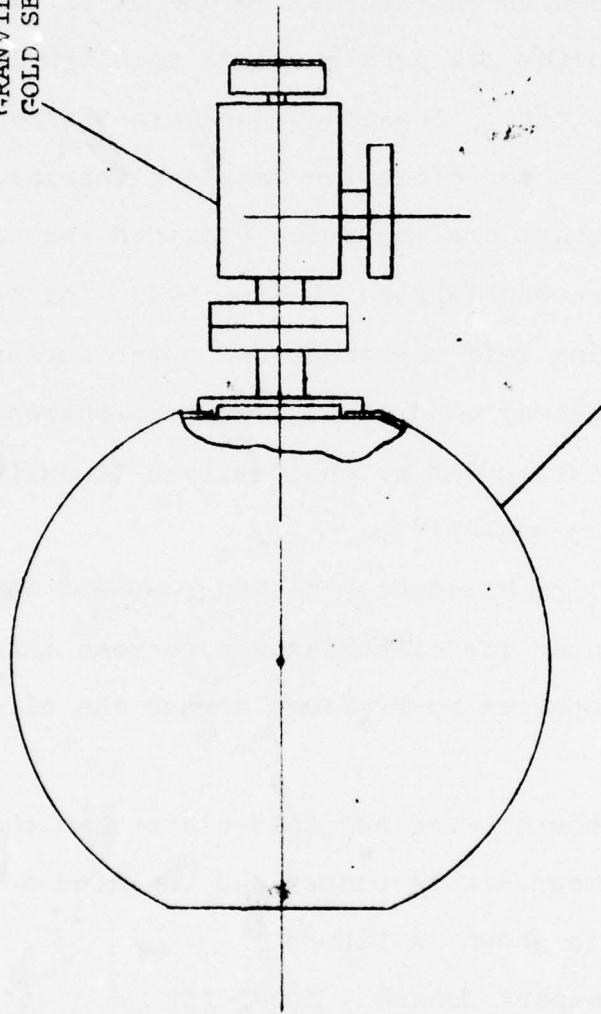
### 3.3 Gas Transport Sphere - Model III

Due to a change in the gas handling mode, a new transport sphere design was initiated. The design was simplified by the elimination of the cold finger. The design incorporated the use of mixing bowls as hemispheres, as a means of reducing the cost of spin forming or hydro-forming hemispheres.

MOD III  
GAS TRANSPORT SPHERE  
FIG. 3

TRANSPORT  
SPHERE

GRANVILLE-PHILLIPS  
GOLD SEAL VALVE  
MR



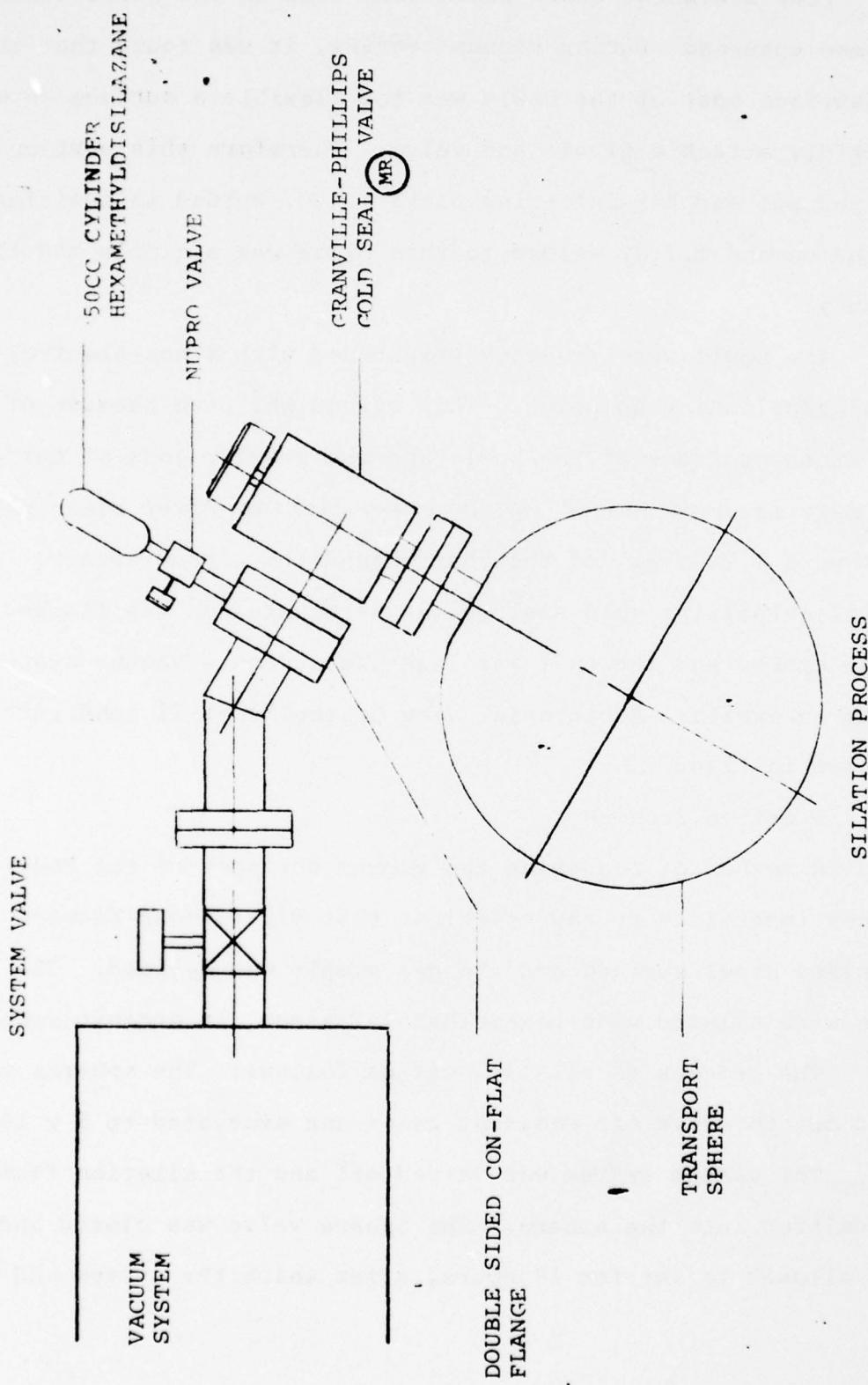


Fig. 4

Four and eight quart bowls were used in the fabrication of these spheres. During vacuum testing, it was found that the flat surface base of the bowls was too flexible a surface on which to rigidly attach a nipple and valve. Therefore this portion was machined out and a reinforcing plate T.I.G. welded in position. Mounted on and T.I.G. welded to this plate was a nipple and flange assembly.

The bowls were diversely brightened with a non-electrolyic cleaning/polishing solution. This method was used because of the thin cross-sections of the bowls and the greater loss of surface area material experienced in electro-polishing. After cleaning, the bowls were T.I.G. welded together around the circumference. A Granville-Phillips gold seal valve was mounted on the flanged end of the sphere and the unit was leak checked on a vacuum system for vacuum integrity. A pictorial view of the Model II configuration is shown in Figure 3.

#### 3.4 Silation Process

A method of rendering the vacuum surfaces of the Model III spheres impervious to any reactions that might occur between the stainless steel surface and the gas sample was devised. The surfaces were silated with hexamethyldisilazane, an organic compound.

The process of silation was as follows: The spheres were baked out to drive off residual gases and evacuated to  $5 \times 10^{-5}$  torr. The vacuum system was valved off and the silation fluid slowly admitted into the sphere. The sphere valve was closed and the unit allowed to set for 24 hours, after which the system and sphere

valves were reopened and the unit pumped down to  $5 \times 10^{-8}$  torr.

The valves were closed and the unit removed from the system.

The transport spheres were ready for lab test prior to flight. A pictorial view of this process is shown in Figure 4.

#### 4.0 CONCLUSION

In the first two transport spheres, i.e. Models I and II, a liquid helium cold finger was required and both spin forming and hydro-forming were utilized in their construction. The Model III transport sphere required no cold finger due to the introduction of a cryogenic tri-sampler; and it was constructed from stainless steel salad bowls. With some reinforcement of these bowls, i.e. the addition of a plate on the bottom of the bowl supporting the valve, they have proved satisfactory and the cost savings over the previous designs were considerable. The process of diversy cleaning and silation of the vacuum surfaces seems to be a reliable method of rendering stainless steel surfaces non-reactive to the air samples. This method has a definite cost saving over gold plating, in addition to increased reliability.

DISTRIBUTION LIST

Director  
Defense Advanced Rsch Proj Agency  
Architect Building  
1400 Wilson Blvd.  
Arlington, VA 22209  
01CY Attn Sto Kent Kresa  
01CY Attn Ltc W A Whitaker  
01CY Attn STO Capt J Justice  
01CY Attn TTO Fred A Koether

Defense Documentation Center  
Cameron Station  
Alexandria, VA 22314  
(12 copies if open public)  
2CY Attn TC

Director  
Defense Intelligence Agency  
Washington, DC 20301  
01CY Attn DT-1 Mr Knoll  
01CY Attn DT-1C

Director  
Defense Nuclear Agency  
Washington DC 20305  
03CY Attn STTI Tech Library  
01CY Attn RAAF P Fleming  
03CY Attn RAAF Charles A Blank  
01CY Attn STST Archives  
01CY Attn STRA  
01CY Attn RAAF Maj John Clark  
01CY Attn RAAF Harold C Fitz Jr

Commander  
Field Command  
Defense Nuclear Agency  
Kirtland AFB, NM 87115  
01CY Attn FCT William S Isengard  
01CY Attn FCPR

Director  
Interservice Nuclear Weapons School  
Kirtland AFB, NM 87115  
01CY Attn Document Control

Director  
Joint Strat TGT Planning Staff JCS  
OFFUTT AFB  
Omaha, NB 68113  
01CY Attn JPST Maj J S Green

Chief  
Livermore Division Fld Command DNA  
Lawrence Livermore Laboratory  
P.O. Box 808  
Livermore, CA 94550  
01CY Attn FCPRL

Commander/Director  
Atmospheric Sciences Laboratory  
U S Army Electronics Command  
White Sands Missile Range, NM 88002  
01CY Attn F Butterfield DRSEL-BL-SY-R  
01CY Attn R Olsen  
01CY Attn M Diamond  
01CY Attn H Ballard  
01CY Attn DRSFL-BL-SY-S F E Niles

Director  
BMD Advanced Tech Ctr  
Huntsville Office  
P.O. Box 1500  
Huntsville, AL 35807  
01CY Attn ATC-T Melvin T Capps  
01CY Attn ATC-O W Davies

Chief C-E Services Division  
U S Army Communications CMD  
Pentagon Rm 1B269  
Washington, DC 20310  
01CY Attn CC-OPS-CE

Dep Chief of Staff for Rsch Dev & ACQ  
Department of the Army  
Washington, DC 20310  
01CY Attn ARMDA-OO  
01CY Attn Safeguard and Space Div

**Commander**  
Harry Diamond Laboratories  
2800 Powder Mill Road  
Adelphi, MD 20783  
02CY Attn DRXDO-NP  
01CY Attn Mildred H Weiner DRXDO  
(CNWDI-INNER ENVELOPE  
ATTN: DRXDO-RBH)

**Commander**  
Trasana  
White Sands Missile Range NM 88002  
01CY Attn R E Dekinder Jr

**Director**  
U S Army Ballistic Research Labs  
Aberdeen Proving Ground, MD 21005  
01CY Attn DRXBR-AM D Snider  
01CY Attn J A Vanderhoff  
01CY Attn DRXBR-CA T J OBrien  
01CY Attn DRXBR-AM J S Batten  
01CY Attn I L Chidsey  
01CY Attn DRXBR-AM G E Keller  
01CY Attn J Heimerl DRXRD-BSP  
01CY Attn John C Mester  
01CY Attn Mark D Kregel  
01CY Attn Tech Lib Edward Baicy

**Commander**  
U S Army Electronics Command  
Fort Monmouth, NH 07703  
01CY Attn DRSFL-PI-ENV Hans A Bo

**Commander**  
U S Army Foreign Science & Tech Ctr  
Charlottesville, VA 22901  
01CY Attn R Jones

**Commander**  
U S Army Materiel Dev & Readiness CMD  
Alexandria, VA 22333  
01CY Attn DRCDF-D Lawrence Flynn

**Commander**  
U S Army Nuclear Agency  
Fort Bliss, TX 79916  
01CY Attn MONA-WE J Berberet

**Chief**  
U S Army Research Office  
P.O. Box 12211  
Triangle Park, NC 27709  
01CY Attn CRDARD-P Robert Mace

**Chief of Naval Operations**  
Navy Department  
Washington, DC 20350  
01CY Attn OP 985

**Chief of Naval Research**  
Navy Department  
Arlington, VA 22217  
01CY Attn Code 464 Thomas P Quinn  
01CY Attn Code 464 R Gracen Joiner  
01CY Attn Code JTU Joh G Dardis  
01CY Attn Code 427 Cdr Ronald J Oberle

**Commander**  
Naval Electronics Laboratory Center  
San Diego, CA 92152  
01CY Attn William F Moler  
01CY Attn Code 2200 Jurgen Richter  
01CY Attn Code 2200 Herbert Hughes  
01CY Attn Code 2200 Richard Pappert  
01CY Attn Code 2200 Ilan Rothmuller

**Superintendent (Code 1424)**  
Naval Postgraduate School  
Monterey, CA 93940  
(Destres No CNWDT Documents)  
01CY Attn Code 61 MN E A Milne

**Director**  
Naval Research Laboratory  
Washington, DC 20375  
01CY Attn Code 7701 Jack D Brown  
01CY Attn Code 7127 Charles Y Johnson  
01CY Attn Code 7750 J Davis  
01CY Attn Code 7750 Wahar Ali  
01CY Attn Code 7700 Timothy P Coffey  
01CY Attn Code 7750 Klaus Hain  
01CY Attn Code 7750 Paul Juluenne  
01CY Attn Code 7730 Edgar A McClean  
01CY Attn Code 2027 Tech Lib  
01CY Attn Code 7750 Darrell F Strobel

**Commander**  
Naval Surface Weapons Center  
White Oak, Silver Spring, MD 20910  
O1CY Attn Code WA501 Navy Nuc Prgms Off  
O1CY Attn L Rudlin  
O1CY Attn D J Land

**Headquarters**  
Air Force Systems Command  
Andrews AFB  
Washington, DC 20331  
O1CY Attn SDR

**AF Geophysics Laboratory, AFSC**  
Hanscom AFB, MA 01731  
O1CY Attn LKB A Faire  
O1CY Attn OPR Alva T Stair  
O1CY Attn OPR J Rodgers  
O1CY Attn LKD Rocco S Narcisi  
O1CY Attn LKB John Paulson  
O1CY Attn LKB L Weeks  
O1CY Attn OPR James C Ulwick  
O1CY Attn LKB Edmond Murad  
O1CY Attn LKC D Golomb  
O1CY Attn LKB Kenneth S W Champion  
O1CY Attn LKB T J Keneshea  
O1CY Attn LKB William Swider Jr  
O1CY Attn LKD C R Philbrick  
O1CY Attn OP John S Garing  
O1CY Attn LKS F R Innes  
O1CY Attn LKS R A Van Tassel  
O1CY Attn LKO Robert E Huffman  
O1CY Attn OPR J Kennealy  
O1CY Attn OPR F Delgreco  
O1CY Attn OPR Harold Gardner  
O1CY Attn OPR J H Schummers  
O1CY Attn OPR R ONeill  
O1CY Attn OPR R E Murphy  
O1CY Attn SUDL AFGL Rsch LIB

**Headquarters**  
Electronic Systems Division, (AFSC)  
Hanscom AFB, MA 01731  
O1CY Attn FSTI

**Commander**  
Foreign Technology Division, AFSC  
Wright-Patterson AFB, OH 45433  
O1CY Attn TD-RTA Library  
O1CY Attn Maj E Frey

**HQ USAF/IN**  
Washington, DC 20330  
O1CY Attn INS

**HQ USAF/RD**  
Washington, DC 20330  
O1CY Attn RDQ H F Kerr  
O1CY Attn RD DCS D Rand  
O1CY Attn RDQPN

**Commander**  
Rome Air Development Center, AFSC  
Griffiss AFB, NY 13440  
O1CY Attn V Coyne  
O1CY Attn EMTLD Doc Library  
O1CY Attn OCSF J J Simons  
O1CY Attn TDR

**Samsø/SZ**  
Post Office Box 92960  
Worldway Postal Center  
Los Angeles, CA 90009  
(Space Defense Systems)  
O1CY Attn SZJ Major Lawrence Doan

**AFTAC**  
Patrick AFB, FL 32925  
O1CY Attn TF/Maj Wiley  
O1CY Attn TF/Maj E Hines  
O1CY Attn TN

**Commander in Chief**  
Strategic Air Command  
OFFUTT AFB, NB 68113  
O1CY Attn XPPS Maj Brian G Stephan

Sandia Laboratories

P.O. Box 5800

Albuquerque, NM 87115

O1CY Attn Doc Con For D A Dahlgren  
Org 1722

O1CY Attn Doc Con For Frank P Hudson  
Org 1722

O1CY Attn Doc Con for Org 3422-1  
Sandia RPT Coll

O1CY Attn Doc Con for Clarence R Mehl  
Org 5230

O1CY Attn D M Rohrer MS 518

O1CY Attn Doc Con for E A Bryant  
(No DASIAC)

O1CY Attn Doc Con for W M Hughes MS 559

O1CY Attn Doc Con for W D Barfield

O1CY Attn Doc Con for Marge Johnson

O1CY Attn Doc Con for William Maier

O1CY Attn Doc Con for Martin Tierney  
J-10

O1CY Attn Doc Con for David W Steinhaus

U S Energy Rsch & Dev Admin

Division of Headquarters Services

Library Branch G-043

Washington, DC 20545

O1CY Attn Doc Con for Class Tech Lib

Albany Metallurgy Research Center

U. S. Bureau of Mines

P.O. Box 70

Albany, OR 97321

O1CY Attn Eleanor Abshire

Argonne National Laboratory

Records Control

9700 South Cass Avenue

Argonne, IL 60439

O1CY Attn Doc Con for Gerald T Reedy

O1CY Attn Doc Con for Len Leibowitz

O1CY Attn Doc Con for David W Green

O1CY Attn Doc Con for S Gabelnick

O1CY Attn Doc Con for Lib Svcs Rpts Sec

O1CY Attn Doc Con for A C Wahl

Central Intelligence Agency

Attn: RD/SI Rm 5G48 Hq Bldg

Washington, DC 20505

O1CY Attn NED/OSI - 2G48 HQS

Department of Commerce

National Bureau of Standards

Washington, DC 20234

(All Corres: Attn SFC Off)

O1CY Attn K Kessler

O1CY Attn George A Sinnatt

O1CY Attn J Cooper

O1CY Attn Stanley Abramowitz

O1CY Attn M Krauss

O1CY Attn Lewis H Gevantman

Division of Military Application

U. S. Energy Rsch & Dev Admin

Washington, DC 20545

O1CY Attn Doc Con for Maj D A Haycock

University of California

Lawrence Livermore Laboratory

P.O. Box 808

Livermore, CA 94550

O1CY Attn D J Wuebbles L-142

O1CY Attn W H Duewer Gen L-404

O1CY Attn G R Haugen L-404

O1CY Attn Julius Chang L-71

Department of Commerce

Office of Telecommunications

Institute for Telecom Science

Boulder, CO 80302

O1CY Attn L A Berry

O1CY Attn William F Utlaut

Los Alamos Scientific Laboratory

P.O. Box 1663

Los Alamos, NM 87545

O1CY Attn Doc Con for John S Malik

O1CY Attn Doc Con for Groud CMR-T

O1CY Attn Doc Con for T Bieniewski CMB-1

O1CY Attn Doc Con for Herman Hoerlin

O1CY Attn Doc Con for J Judd

O1CY Attn Doc Con for John Zinn

Department of Transportation

Office of the Secretary

TAD-44.1, Room 10402-B

400 7th Street S.W.

Washington, D.C. 20590

O1CY Attn Richard L Strombotne TST-8

O1CY Attn R Underwood

NASA

Goddard Space Flight Center  
Greenbelt, MD 20771

O1CY Attn A Tempkin

O1CY Attn S J Bauer

O1CY Attn Technical Library

O1CY Attn A C Aiken

NASA

600 Independence Avenue S W  
Washington, DC 20546

O1CY Attn R Fellows

O1CY Attn D P Cauffman

O1CY Attn LTC D R Hallenbeck Code SG

O1CY Attn A Gessow

NASA

Langley Research Center

Langley Station

Hampton, VA 23365

O1CY Attn Charles Schexnayder MS-168

NASA

Ames Research Center

Moffitt Field, CA 94035

O1CY Attn N-254-3 Neil H Farlow

O1CY Attn N-254-4 Walter L Starr

O1CY Attn M-254-4 R Whitten Uncl Only

O1CY Attn N-245-4 Ilia G Popoff

National Oceanic & Atmospheric Admin  
Environmental Research Laboratories  
Department of Commerce

Boulder, CO 80302

O1CY Attn Fred Fehsenfeld

O1CY Attn Eldon Ferguson

O1CY Attn J W Pope

O1CY Attn George C Reid Aeronomy Lab

National Science Foundation

1800 G Street, N.W.

Washington, DC 20556

(No classified to this address)

O1CY Attn E P Todd

O1CY Attn R S Zapolksky

O1CY Attn W D Adams

O1CY Attn Rolf Sinclair

O1CY Attn R Manka

O1CY Attn Fred D White

O1CY Attn M K Wilson

Aero-Chem Research Laboratories, Inc.

P.O. Box 12

Princeton, NJ 08540

O1CY Attn A Fontijn

O1CY Attn H Pergament

O1CY Attn Hartwell F Calcote

Aerodyne Research, Inc.

Bedford Research Park

Crosby Drive

Bedford, MA 01730

O1CY Attn E Bien

O1CY Attn M Camac

Aeronomy Corporation

217 S Neil Street

Champaign, IL 61820

O1CY Attn S A Bowhill

Aerospace Corporation

P.O. Box 92957

Los Angeles, CA 90009

O1CY Attn N Cohen

O1CY Attn R J McNeal

O1CY Attn Sidney W Kash

O1CY Attn R Grove

O1CY Attn T Widhopf

O1CY Attn R D Rawcliffe

O1CY Attn Julian Reinheimer

O1CY Attn Irving M Garfunkel

O1CY Attn V Josephson

O1CY Attn Harris Mayer

O1CY Attn T Taylor

Avco-Everett Research Laboratory, Inc.

2385 Revere Beach Parkway

Everett, MA 02149

O1CY Attn George Sutton

O1CY Attn C W Von Rosenberg Jr.

O1CY Attn Technical Library

Battelle Memorial Institute

505 King Avenue

Columbus, OH 43201

O1CY Attn Richard K Thatcher

O1CY Attn Stotac

O1CY Attn Donald J Hamman

The Trustees of  
Boston College  
Chestnut Hill Campus  
Chestnut Hill, MA 02167  
02CY Attn Chairman Dept of Chem

Brown Engineering Company, Inc.  
Cummings Research Park  
Huntsville, AL 35807  
01CY Attn N Passino  
01CY Attn Ronald Patrick

California at Riverside, Univ of  
Riverside, CA 92502  
01CY Attn James N Pitts Jr  
01CY Attn Alan C Lloyd

California at San Diego, Univ of  
Bldg. 500 Matthews Campus  
3175 Miramar Road  
1 A Jolla, CA 92037  
01CY Attn S C LIN

California Institute of Technology  
Jet Propulsion Laboratory  
4800 Oak Park Grove  
Pasadena, CA 91103  
01CY Attn Joseph Ajello

California University of  
Berkeley, Campus, Room 8  
2543 Channing Way  
Berkeley, CA 94720  
(Class Mail to: Attn Sec Off)  
01CY Attn F Mozer  
01CY Attn Harold Johnston  
01CY Attn Dept of Chem W H Miller

California, State of  
Air Resources Board  
9528 Telstar Avenue  
El Monte, CA 91731  
01CY Attn Leo Zafonte

Calspan Corporation  
P.O. Box 235  
Buffalo, NY 14221  
01CY Attn Robert A Fluegge  
01CY Attn M G Dunn  
01CY Attn W Wurster  
01CY Attn C E Treanor  
01CY Attn G C Valley

Colorado, University of  
Office of Contracts and Grants  
380 Administrative Annex  
Boulder, CO 80302  
01CY Attn C Lineberger JILA  
01CY Attn A Phelps JILA  
01CY Attn C Beaty JILA  
01CY Attn Charles A Barth LASP

Columbia University, The Trustees  
in the City of New York  
IA Mont Doherty Geological  
Observatory - Torrey Cliff  
Palisades, NY 10964  
01CY Attn B Phelan

Columbia University, The Trustees of  
City of New York  
116th Street & Broadway  
New York, NY 10027  
01CY Attn Sec Officer H M Foley  
01CY Attn Richard N Zarf

Concord Sciences  
P.O. Box 119  
Concord, MA 01742  
01CY Attn Emmett A Sutton

Denver, University of  
Colorado Seminary  
Denver Research Institute  
P.O. Box 10127  
Denver, CO 80210  
(Only 1 copy of class Rpts)  
01CY Attn Sec Officer for Mr Van Zyl  
01CY Attn Sec Officer for David Murcrary

**Econometrics**  
718 Willow Glen Road  
Santa Barbara, CA 93105  
01CY Attn Nyle G Otterback

**General Research Corporation**  
P.O. Box 3587  
Santa Barbara, CA 93105  
01CY Attn H H Lewis  
01CY Attn John Ise Jr

**Epsilon Laboratories, Inc.**  
Preston Court  
Bedford, MA 01730  
01CY Attn John Calchines  
01CY Attn Henry Miranda  
01CY Attn Carl Accardo

**General Research Corporation**  
Washington Operations  
Westgate Research Park  
7655 Old Springhouse Road, Suite 700  
McLean, VA 22101  
01CY Attn Thomas M Zakrzewski

**FSL, Inc.**  
495 Java Drive  
Sunnyvale, CA 94086  
01CY Attn James Marshall  
01CY Attn W R Bell

**Geophysical Institute**  
University of Alaska  
Fairbanks, AK 99701  
(All Class Attn: Security Officer)  
01CY Attn Henry Cole  
01CY Attn R Parthasarathy  
01CY Attn Neal Brown (Uncl only)  
01CY Attn B J Watkins  
01CY Attn I N Davis (Uncl only)  
01CY Attn J S Wagner Physics Dept  
01CY Attn D J Henderson

**General Electric Company**  
Space Division  
Valley Forge Space Center  
Goddard Blvd King of Prussia  
P.O. Box 8555  
Philadelphia, PA 19101  
01CY Attn T Bauer  
01CY Attn Robert H Edsall  
01CY Attn P Zavitsanos  
01CY Attn M H Bortner Space Sci Lab  
01CY Attn E Alyfa  
01CY Attn J Burns  
01CY Attn M Linevsky

**Govt Fiscal Relations & Patent Off**  
275 Admin Building AG-70  
University of Washington  
Seattle, WA 98195  
01CY Attn Kenneth C Clark  
01CY Attn R Geballe

**General Electric Company**  
Tempo-Center for Advanced Studies  
816 State Street (P.O. Drawer QO)  
Santa Barbara, CA 93102  
01CY Attn Dasiac Art Faryok  
01CY Attn Tim Stephens  
01CY Attn Don Chandler  
01CY Attn Warren S Knapp  
01CY Attn B Gambill  
01CY Attn Dasiac

**Harvard University**  
Department of Atmospheric Sciences  
Pierce Hall  
Cambridge, MA 02138  
01CY Attn Michael B McElroy

**General Motors Corporation**  
Delco Electronics Division  
Santa Barbara Operations  
6767 Hollister Avenue  
Goleta, CA 93107  
01CY Attn Robin I Primich

**HSS, Inc.**  
2 Alfred Circle  
Bedford, MA 01730  
01CY Attn H Stewart  
01CY Attn M P Shuler  
01CY Attn Donald Hansen

TIT Research Institute  
10 West 35th Street  
Chicago, IL 60616  
O1CY Attn Technical Library

Institute for Defense Analyses  
400 Army-Navy Drive  
Arlington, VA 22202  
O1CY Attn Ernest Bauer  
O1CY Attn Hans Wolfhard  
O1CY Attn Joel Bengston  
O1CY Attn Philip A Selwyn

IRT Corporation  
P.O. Box 81087  
San Diego, CA 92138  
O1CY Attn D A Vroom  
O1CY Attn J A Rutherford  
O1CY Attn R H Neynaber

Jaycor  
1401 Camino Del Mar  
Del Mar, CA 92014  
O1CY Attn H B Levine

Johns Hopkins University  
Applied Physics Laboratory  
Johns Hopkins Road  
Laurel, MD 20810  
O1CY Attn Document Librarian

John Hopkins University  
34th & Charles Streets  
Baltimore, MD 21218  
O1CY Attn Joyce J Kaufman

Kaman Sciences Corporation  
P.O. Box 7463  
Colorado Springs, CO 80933  
O1CY Attn Frank H Shelton  
O1CY Attn B J Bittner  
O1CY Attn P Jesson

Kent State University  
Dept of Chemistry  
Kent, OH 44242  
O1CY Attn W C Fernelius

Lockheed Missiles and Space Company  
3251 Hanover Street  
Palo Alto, CA 94304  
O1CY Attn Billy M McCormac Dept 52-54  
O1CY Attn Martin Walt Dept 52-10  
O1CY Attn Richard G Johnson Dept 52-12  
O1CY Attn Tom James  
O1CY Attn Robert C Gunton Dept 52-14  
O1CY Attn Robert D Sears Dept 52-14  
O1CY Attn J B Reagan D/52-12  
O1CY Attn John Kumer  
O1CY Attn John L Kulander Dept 52-14

Lowell, University of  
Center for Atmospheric Research  
450 Aiken Street  
Lowell, MA 01854  
O1CY Attn G T Best

Maryland, University of  
Administration Building  
College Park, MD 21030  
O1CY Attn Dept of Physics H Griem  
O1CY Attn J Vanderslice Chem Dept  
O1CY Attn Robert J Munn Dept of Chem  
O1CY Attn T J Rosenberg

Maxwell Laboratories, Inc.  
9244 Balboa Avenue  
San Diego, CA 02123  
O1CY Attn Victor Fargo

McDonnell Douglas Corporation  
5301 Bolsa Avenue  
Huntington Beach, CA 92647  
O1CY Attn A D Goedeke  
O1CY Attn William Olsen  
O1CY Attn J Moule

Midwest Research Institute  
425 Volker Boulevard  
Kansas City, MO 64110  
O1CY Attn Physics SFC Frank T Greene  
O1CY Attn Physics Sec Thomas H Milne

Minnesota, University of  
2030 University Avenue, S.F.  
Minneapolis, MN 55414  
(No classified to this address)  
O1CY Attn J R Winkler

Minnesota, University of  
Morris Campus  
Morris, MN 56267  
01CY Attn Merle Hirsch

Photometrics, Inc.  
442 Marrett Road  
Lexington, MA 02173  
01CY Attn Irving L Kofsky

Mission Research Corporation  
735 State Street  
Santa Barbara, CA 93101  
01CY Attn Dave Sowle  
01CY Attn Ralph Kilb  
01CY Attn W F Crevier  
01CY Attn Conrad L Longmire  
01CY Attn Neal J Carron  
01CY Attn R Hendrick  
01CY Attn R N Wilson  
01CY Attn R Bogusch  
01CY Attn M Scheibe  
01CY Attn D Archer  
01CY Attn D Sappenfield  
01CY Attn P Fischer

Physical Dynamics Inc.  
P.O. Box 1069  
Berkeley, CA 94701  
01CY Attn A Thompson  
01CY Attn Joseph B Workman

Mitre Corporation, The  
P.O. Box 208  
Bedford, MA 01730  
01CY Attn S A Morin M/S  
01CY Attn J N Freedman

Physical Sciences, Inc.  
30 Commerce Way  
Woburn, MA 01801  
01CY Attn Kurt Wray  
01CY Attn R L Taylor

National Academy of Sciences  
Attn: National Materials Advisory  
2101 Constitution Avenue  
Washington, DC 20418  
02CY Attn Edward R Dyer  
01CY Attn J R Stevers  
01CY Attn William C Bartley

Physics International Company  
2700 Merced Street  
San Leandro, CA 94577  
01CY Attn Doc Con for Tech Lib

New York at Buffalo, State Univ of  
Buffalo, NY 14214  
01CY Attn Gilbert O Brink

Pittsburgh, University of  
the Commonwealth System of Higher Educ  
Cathedral of Learning  
Pittsburgh, PA 15213  
01CY Attn Wade L Fite  
01CY Attn Manfred A Biondi  
01CY Attn Frederick Kaufman  
01CY Attn Edward Gerjudy

Pacific-Sierra Research Corp.  
1456 Cloverfield Blvd.  
Santa Monica, CA 90404  
01CY Attn F C Field Jr

Princeton Univ., The Trustees of  
Forrestal Campus Library  
Box 710  
Princeton University  
Princeton, NJ 08540  
01CY Attn Arnold J Kelly  
(Use P.O. Box 36 for Unclass only)

Pennsylvania State University  
Industrial Security Office  
Room 5, Old Main Building  
University Park, PA 16802  
01CY Attn L Hale  
01CY Attn J S Nisret

R & D Associates  
P.O. Box 9695  
Marina Del Rey, CA 90291  
01CY Attn R P Turco  
01CY Attn Richard Latter  
01CY Attn Robert F Lelevier  
01CY Attn D Dee  
01CY Attn R G Lindgren  
01CY Attn Charles H Humphrey  
01CY Attn Bryan Gabbard  
01CY Attn H A Dry  
01CY Attn Forrest Gilmore  
01CY Attn Albert I Latter

R & D Associates  
1815 N. Ft. Myer Drive  
11th Floor  
Arlington, VA 22209  
01CY Attn Herbert J Mitchell  
01CY Attn J W Rosengren

Rand Corporation, The  
1700 Main Street  
Santa Monica, CA 90406  
01CY Attn Culien Crain

Rice University  
Department of Space Science  
Houston, TX 77058  
01CY Attn Ronald E Stebrings

Rice University, William Marsh  
P.O. Box 2692  
Houston, TX 77001  
(All Corres Attn: Industiral Sec Sup)  
01CY Attn J Chamberlain

Riverside Research Institute  
80 West End Avenue  
New York, NY 10023  
01CY Attn J B Minkoff  
01CY Attn G Glaser  
01CY Attn Donald H Koppel

Science Applications, Inc.  
P.O. Box 2351  
La Jolla, CA 92038  
01CY Attn Daniel A Hamlin  
01CY Attn Robert W Lowen  
01CY Attn Ben Myers

Science Applications, Inc.  
Huntsville Division  
2109 W. Clinton Avenue  
Suite 700  
Huntsville, AL 35805  
01CY Attn Noel R Byrn

Sechrist, Professor Chalmers F.  
155 Electrical Enginnering Bldg.  
University of Illinoiis  
Urbana, IL 61801  
01CY Attn C Sechrist

Southern California, Univ of  
University Park  
Los Angeles, CA 90007  
01CY Attn S W Benson

Stanford Research Institute  
333 Ravenswood Avenue  
Menlo Park, CA 94025  
01CY Attn Felix T Smith (Uncl Only)  
01CY Attn D J Hildenbrand  
01CY Attn L E Cobb  
01CY Attn G Black  
01CY Attn J T Moseley  
01CY Attn Burt R Gasten  
01CY Attn J Lomax  
01CY Attn R D Hake Jr  
02CY Attn Walter G Chestnut  
01CY Attn James R Peterson  
01CY Attn Arthur Lee Whitson  
01CY Attn Ray L Leadabrand  
01CY Attn Allen M Peterson  
01CY Attn T G Slanger  
01CY Attn Ronald White

Stanford Research Institute  
1611 North Kent Street  
Arlington, VA 22209  
01CY Attn Warren W Berning

Stanford Research Institute  
306 Wynn Drive, N. W.  
Huntsville, AL 35805  
01CY Attn MacPherson Morgan

Systems, Science and Software, Inc.  
P.O. Box 1620  
La Jolla, CA 92038  
01CY Attn Ralph C SKlarew

Technology International Corporation  
75 Wiggins Avenue  
Bedford, MA 01730  
01CY Attn W P Boquist

TRW Systems Group  
One Space Park  
Redondo Beach, CA 90278  
01CY Attn R Watson Rl/1096  
01CY Attn J F Friitzenich Rl-1196  
01CY Attn R K Plebuch  
01CY Attn Tech Info Center/S-1930

Science Applications, Inc.  
P.O. Box 2351  
La Jolla, CA 92038  
01CY Attn Daniel A Hamlin  
01CY Attn Robert W Lowen  
01CY Attn Ben Myers

Stanford Research Institute  
306 Wynn Drive, N.W.  
Huntsville, AL 35805  
01CY Attn MacPherson Morgan

Science Applications, Inc.  
Huntsville Division  
2109 W. Clinton Avenue  
Suite 700  
Huntsville, AL 35805  
01CY Attn Noel R Byrn

Systems, Science and Software, Inc.  
P.O. Box 1620  
1A Jolla, CA 92038  
01CY Attn Ralph C Sklarew

Sechrist, Professor Chalmers F.  
155 Electrical Engineering Bldg.  
University of Illinois  
Urbana, IL 61801  
01CY Attn C Sechrist

Technology International Corporation  
75 Wiggins Avenue  
Bedford, MA 01730  
01CY Attn W P Boquist

Southern California, Univ of  
University Park  
Los Angeles, CA 90007  
01CY Attn S W Benson

TRW Systems Group  
One Space Park  
Redondo Beach, CA 90278  
01CY Attn R Watson R1/1096  
01CY Attn J F Friichtenicht R1-1196  
01CY Attn R K Pleruch  
01CY Attn Tech Info Center/S-1930

Stanford Research Institute  
333 Ravenswood Avenue  
Menlo Park, CA 94025  
01CY Attn Felix T Smith (Uncl only)  
01CY Attn D J Hildenbrand  
01CY Attn L E Cobb  
01CY Attn G Black  
01CY Attn J T Moseley  
01CY Attn Burt R Gasten  
01CY Attn J Lomax  
01CY Attn R D Hake Jr  
01CY Attn Walter G Chestnut  
01CY Attn James R Peterson  
01CY Attn Arthur Lee Whitson  
01CY Attn Ray L Leadabrand  
01CY Attn Allen M Peterson  
01CY Attn T G Slanger  
01CY Attn Ronald White

United Technologies Corporation  
755 Main Street  
Hartford, CT 06103  
01CY Attn Tober H Bullis  
01CY Attn H Michels

Stanford Research Institute  
1611 North Kent Street  
Arlington, VA 22209  
01CY Attn Warren W Berning

Utah State University  
Logan, UT 84321  
01CY Attn William M More Chemistry Dept  
01CY Attn Kay Baker  
01CY Attn C Wyatt  
01CY Attn D Burt  
01CY Attn Doran Baker

Visidyne, Inc.  
19 Third Avenue  
North West Industiral Park  
Burlington, MA 01803  
01CY Attn T C Degges  
01CY Attn J W Carpenter  
01CY Attn Oscar Manley  
01CY Attn R Waltz

Wayne State University  
1064 MacKenzie Hall  
Detroit, MI 48202  
01CY Attn R H Kummller  
01CY Attn Pieter K Rol Chem Engrg  
& Mat Sci

United Technologies Corporation  
755 Main Street  
Hartford, CT 06103

O1CY Attn Robert H Bullis  
O1CY Attn H Michels

Utah State University  
Logan, UT 84321  
O1CY Attn William M More  
Chemistry Dept.  
O1CY Attn Kay Baker  
O1CY Attn C Wyatt  
O1CY Attn D Burt  
O1CY Attn Doran Baker

Visidyne, Inc.  
19 Third Avenue  
North West Industrial Park  
Burlington, MA 01803  
O1CY Attn T C Degges  
O1CY Attn J W Carpenter  
O1CY Attn Oscar Manley  
O1CY Attn R Waltz

Wayne State University  
1064 MacKenzie Hall  
Detroit, MI 48202  
O1CY Attn R H Kummier  
O1CY Attn Pieter K Rol Chem Engrg  
& Mat Sci

Wayne State University  
Dept. of Physics  
Detroit, MI 48202  
O1CY Attn Walter F Kauppila

Yale University  
New Haven, CT 06520  
O1CY Attn Engrg Dept George J Schultz